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WOODS HOLE OCEANOGRAPHIC INSTITUTION

Reference No. 63-26

ATLANTIC OCEANOGRAPHY

conducted during the period

July 1, 1962 - June 30, 1963

WOODS HOLE, MASSACHUSETTS

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July 1, 1962 - June 30, 1963

compiled by

J. H. Stanbrough

Periodic Status Report

Submitted to Geophysics Branch, Office of Naval Research
Under Contract Nonr-2196(00) (NR-083-004)

September 1963

APPROVED FOR DISTRIBUTION Paul M. Fye
Paul M. Fye, Director

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NORTH ATLANTIC CIRCULATION - L. Valentine Worthington

In July 1962 a short cruise was made on CHAIN to investigate the hypothesis (Worthington 1962) that the major circulation of the North Atlantic is divided into two anti-cyclonic eddies or gyres. Evidence from International Geophysical Year data indicated that the thermocline water east of the Grand Banks had different characteristics from Sargasso Sea water. In particular, the dissolved oxygen content throughout the thermocline was at a much higher level in the more northerly waters than in the Sargasso Sea. It was deduced from this that the Gulf Stream, which transports a large volume of water of the Sargasso Sea type, does not turn south around the Tail of the Banks, but that the strong, narrow currents found to the East of the Banks transport water of different origin.

An essential feature of this proposed circulation system is a trough of low pressure (consisting of cold water) separating the two high cells of the Sargasso Sea gyre and the northern gyre. In this cruise the main attention was focused on the area where the trough was expected to be found. Six bathythermograph sections and one deep oceanographic section were made on a grid oriented northeast/southwest. A definite cold water trough was found on four of the six bathythermograph sections and on the oceanographic section. Neither the temperature or the current field (observed on the GEK) suggested that any considerable volume of water of the Sargasso Type passed across a line drawn between the Tail of the Banks and the intersection of the 40th parallel and the 40th meridian.

An interesting study (Clark 1963) was made of the scattering layer observed in these sections. It was found that on all six sections the deep (200 fathoms) scattering layer rose to shallower levels when the cold trough was crossed. On one of these occasions the abrupt rise and fall of the scattering layer was observed between the routine bathythermograph lowerings and it appears likely that a closer spacing of bathythermographs would have shown the cold trough on all six sections. Plankton tows made during this cruise are dealt with in the same study (Clark 1963), and they are encouraging to the two gyre hypothesis; they suggest that there are three differing populations, one in the Sargasso Sea, one in the cold trough and one in the waters of the northern gyre.

On the other hand, the oxygen contrast between the two gyres was not as marked as it had been during the International Geophysical Year. The oxygen values throughout the thermocline at stations made in the Sargasso Sea were higher than in any previous data from that sea, and it seems likely that a considerable exchange of water had taken place across the trough at some time before 1962.

Water budget for the two-gyre circulation system is presented in Figure 1. Each streamline represents 10 million m^3/sec. It is based on a number of sections across the Gulf Stream, the cold trough and the currents east of the Grank Banks. The reference level used is 2,000 m, because nearly all the stations reach this depth.

Further work in this area is planned for the early months of 1964 in ATLANTIS II since this postulated circulation pattern cannot be fully relied upon at present.

A paper entitled "Anomalous conditions in the slope water area in 1959" has been submitted for publication to the Journal of the Fisheries Research Board of Canada. It appears that in the spring of 1959 a large mass of cold water flowed from the Labrador Sea around the Tail of the Grand Banks and to a great extent replaced the slope water which is normally found between the Gulf Stream and the continental shelf east and south of the United States and south of Canada. This cold mass of water was first noticed in a section made on CRAWFORD in June 1959 along the meridian 57°30'W. Examination of bathythermograms for 1959 indicated that this cold water was not confined to the CRAWFORD section but was found to be wide-spread in the Slope water area. The summer of 1959 was characterized by a very high incidence of fog at coastal stations in the northeastern United States and in southern Canada.

The cause of this influx of cold water is thought to have been related to an event in the North Atlantic weather pattern in the winter of 1958-1959. Starting in December 1958 and persisting through January and part of February 1959 the Icelandic low weakened and shifted from its normal position resulting in prolonged and intense easterly gales south of Greenland.

The amount of water movement involved (estimated at 50 million m^3/sec) seems very large. It is roughly one half the volume transport of the Gulf Stream. If such large water movements can indeed be initiated by anomalous weather patterns which persist for only about two months we should know more about them. The paper is a preliminary suggestion that such events are at least possible.

An examination of deep temperature measurements made in the Caribbean in the years 1933, 1934, 1937 and 1958 has raised the question of whether or not the deepest waters of the Caribbean are becoming warmer. The four principal basins, the Yucatan, Cayman, Colombian and Venezuelan have been examined to the extent that the rather scarce deep temperature measurements persist. Roughly speaking the deepest water in the Cayman Basin appears to have been 0.03° warmer in 1958 than in the earlier surveys, the Yucatan 0.02° warmer, the Colombian 0.01° warmer and the Venezuelan essentially unchanged. The 1958 data have been put through a computer program to determine stability (10^8 E.). All the basins except the Venezuelan appear to have a layer (varying in thickness)

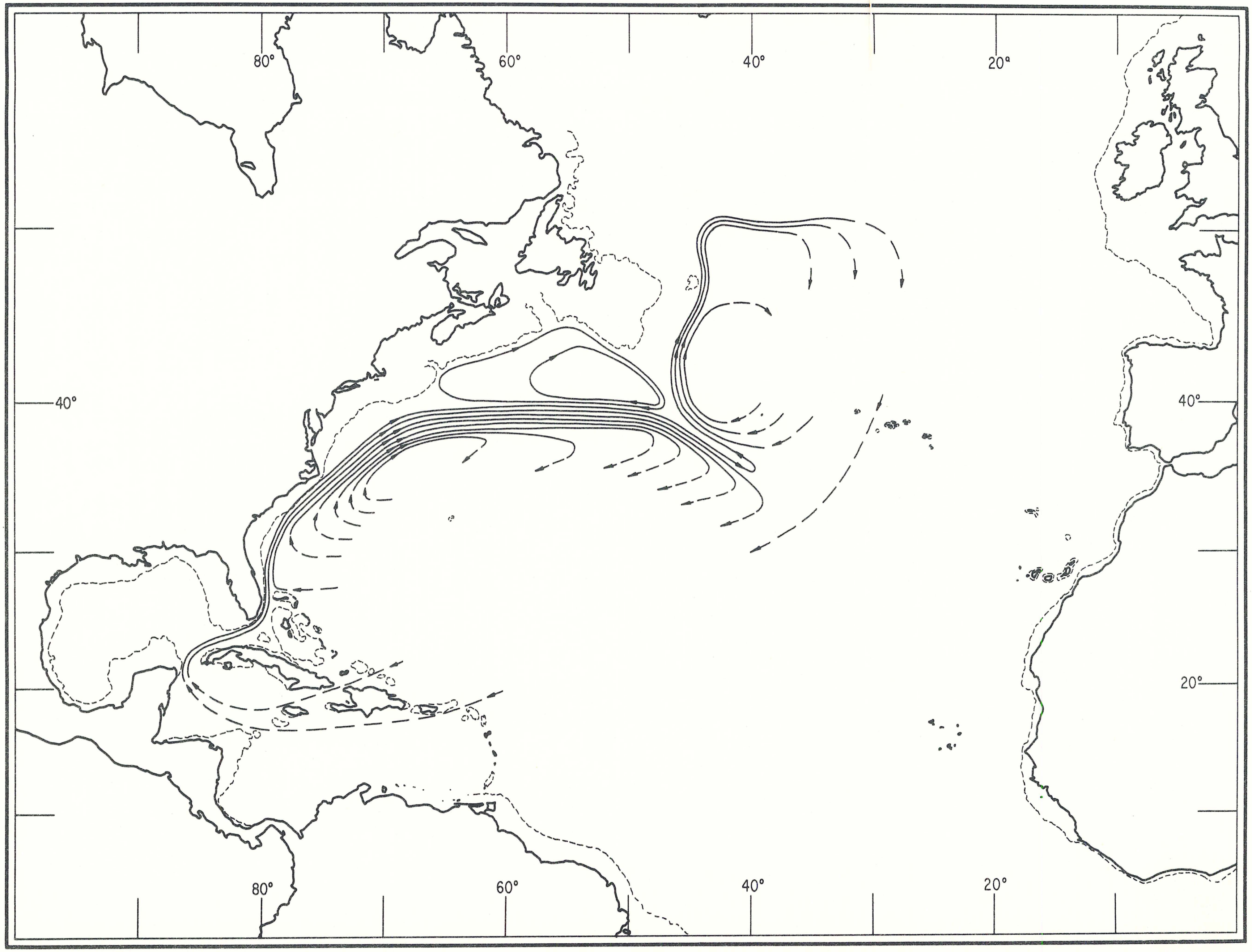

Figure 1. Water budget, relative to the 2,000 meter surface for the North Atlantic.

of neutrally stable water from the bottom up. This suggests that the warming may have been caused by heat flow through the bottom which would be consistent with neutral stability.

An opportunity to check on this matter has been presented in that CRAWFORD will be concluding a project in West Indian waters in early September 1963. It is planned to make two detailed oceanographic sections from the Atlantic into the Caribbean through the two important sills connecting them. One section will be run through the Anegada and Virgin passages into the Venezuelan and Colombian basins and the other through the Windward passage into the Cayman and Yucatan Basins. We now have much more accurate reversing thermometers than were available in 1958 and it is hoped that this interesting question may in part be answered.

In a previous work (Worthington and Metcalf 1960) an attempt was made to describe the deep potential temperature/salinity relationship in the Atlantic Ocean. Since that paper was prepared (it was read at the International Council for the Exploration of the Sea meeting in Copenhagen in October 1959) a great many more reliable observations have become available, particularly in the northern North Atlantic. The German results from the International Geophysical Year and the more recent cruise of M/S ERIKA DAN under charter to this Institution have filled in the major gaps in our coverage of the Atlantic.

The clearest method of presenting the deep data seems to be to prepare charts of salinity at different potential temperature surfaces; these show very clearly such features as the outflow from the Norwegian Sea and the Mediterranean Sea into the Atlantic. Charts have been prepared of salinity at each 0.2° potential temperature increment from 1.4° to 4°C. These charts have a drawback because the precise salinity measurements necessary for their compilation were spread in time between the years 1954 and 1962. This hardly approaches the synoptic ideal. The form in which these charts will be published has not yet been decided, but it is felt they may be useful tools for the future study of deep water circulation.

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MEDITERRANEAN OUTFLOW - Frederick C. Fuglister

The study of the Mediterranean water in the Atlantic Ocean stems from a long-term interest in the alleged extraordinary influence of the inflow of Mediterranean water on the salinity of the Atlantic Ocean, and from the results of the last DISCOVERY II International Geophysical Year cruise in the Bay of Cadiz in 1958.

The data from this cruise clearly delineate the core, or stream, of highly saline water flowing from the Straits of Gibraltar along the bottom in the northern portion of the Bay of Cadiz. The salinity and the density of the water rapidly decreases as it mixes with the fresher water of the Atlantic so that by the time it reaches Cape St. Vincent at the southwest corner of the Iberian Peninsula the maximum observed salinity has changed from over 38.0‰ to 36.5‰ and the sigma-t from 29.0 to 27.7. At this point the core of high salinity water probably contains less than 40% of pure Mediterranean water.

According to Wüst this water can be traced over virtually the entire North and South Atlantic and the percentage of Mediterranean water present at any point can be determined from a curve for the Temperature/Salinity relationship in the core layer of this upper North Atlantic Deep Water. Dr. C.O'D. Iselin, using the Helland-Hansen anomaly method, shows that the water extends over a much smaller area, confined to the North Atlantic, north of 20° N. Dr. Albert Defant believes that this difference can be explained by differences in the definition of the "Mediterranean Water" but he insists that "traces" of Mediterranean Water can be followed far into the South Atlantic (Defant 1961).

It is certainly important to define the Mediterranean water carefully but the extent to which this water spreads is determined actually by the end point, or end points, chosen to represent zero Mediterranean Water. Presumably, in the "core" method, the end point occurs where the core or tongue ceases to exist. The question here is: to what extent does the presence of a core, say a layer of maximum salinity, depend on the presence of another core or minimum layer? Would the "traces" of Mediterranean Water at 2,000 meters in the South Atlantic be recognizable if the core of relatively fresh water, the Subantarctic Intermediate Water, were not present?

Questions of this nature are being investigated because it appears that the influence of the Mediterranean outflow on the thermohaline structure of the Atlantic is frequently somewhat exaggerated. The North Atlantic would probably be the most saline of the world's oceans even if it were cut off from this source.

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MEDITERRANEAN CIRCULATION - Arthur R. Miller

The last of a series of three cruises to the Mediterranean Sea was completed in 1962. These cruises had as objectives the determination and observation of the processes involved in vertical circulation and the formation of deep and intermediate waters. These processes required that the investigations be carried out in the winter season.

Temperature and salinity profiles have been drawn and the T-S characters of the waters have been determined. A significant feature of the T-S analysis is the deep seasonal change occurring in the lower Aegean Sea. A smaller degree of seasonal change occurs in the Western Mediterranean. Periodic and aperiodic large scale changes occur in the Adriatic which is a strong contributor to Eastern Mediterrean circulation.

Oxygen values from these cruises have been compared with previous work and have been plotted. The minimum oxygen layer in the Western Mediterranean appears to be the source for water passing into the Atlantic. Assuming this layer to be the nutrient-rich layer from the inverse relationship between oxygen and phosphate, the Mediterranean is impoverished by this outflow.

The Mediterranean Sea gets little fresh water contribution from run-off and rainfall, hence a dominant part of its complicated circulatory system depends on the transfer of energy at the sea surface through evaporative processes and incoming radiation. Evaporating pan measurements show that, in terms of salinity increase, a rise in surface salinity of 0.1°/oo per hour due to evaporation is normal for the area. Incoming radiation may offset the instability of surface conditions to some extent but evaporation is a strong influence in the vertical circulation of the Mediterranean where the range of density is relatively small.

In February and March 1963, Paul Tchernia from the Laboratoire d'Oceanographie, Paris, and Henry Charnock, National Institute of Oceanography, England, were in Woods Hole collaborating in the analyses and data preparation. This effort will be brought to a completion following the cruise of the ATLANTIS II to the Indian Ocean, July-December 1963.

Papers presented during this period were as follows: "The Use of Net Radiometers at Sea" by Robert G. Munns, "Direct Observations of Subsurface Currents" by John Bruce, and "Circulation Problems in the Mediterranean" by A.R. Miller. The above were presented at the NATO Summer School on Air-Sea Interaction at Imperial College, London. A paper entitled "Physical Oceanography of the Mediterranean" was presented at a congress in Monaco of the International Commission for the Scientific Exploration of the Mediterranean Sea.

A paper entitled "Dry Squall in the Mediterranean" by Arthur R. Miller has been accepted for publication in the Marine Observer. Another paper entitled

"The Oxygen Question: The Solubility of Oxygen in Sea Water" by Arthur R. Miller has been submitted for publication to the Journal of Marine Research.

EQUATORIAL CURRENT SYSTEM - William G. Metcalf

The Equatorial Current System has been the subject of considerable descriptive study for many years, but the recent discovery or rediscovery of the Equatorial Undercurrent in both the Atlantic and Pacific Oceans has started a major reappraisal of the system.

The Atlantic Equatorial Undercurrent was described by Buchanan in several papers between 1886 and 1895, but his work was largely ignored until recently. Various expeditions since Buchanan's time failed to detect the Undercurrent or at least failed to appreciate its nature primarily because it is so thin from top to bottom that the usual sampling techniques did not delineate its primary feature, the salinity maximum.

Alerted by the work of Cromwell, Montgomery and Stroup in the Pacific in 1954 and by the startling wire angles encountered along the Equator during the International Geophysical Year survey, observing techniques were designed to sample the current in much greater detail than had previously been attempted. In 1961 on CHAIN cruise 17, measurements of the Undercurrent were made at 18°30'West, and at 13°30'West.

With this background, a two-ship survey of the region somewhat west of the above-mentioned observations was planned for the winter and spring of 1963. As it turned out, the work became a part of the International Cooperative Investigations of the Tropical Atlantic. Coordinated by the U.S. Bureau of Commercial Fisheries, the study was given the name EQUALANT I.

R/V CRAWFORD was engaged primarily in making a physical oceanographic survey consisting of hydrographic stations and in situ salinometer lowerings between 10° North and South and between 25° and 40° West. Figure 2 shows the positions and types of stations made during this survey. Six north-south and two east-west sections were made. At the same time, R/V CHAIN placed Richardson current meters near the Equator on most of the sections. In addition, CRAWFORD launched several parachute drogues in the Undercurrent. BT observations were made hourly underway and at each station.

The accumulated data are being studied at present. In all sections, the Undercurrent was found flowing to the East below the surface. The surface current appeared to vary, apparently with the development of the Trade Winds. The high salinity core of the Undercurrent can definitely be traced to the reservoir of high salinity water found close to the bulge of Brazil. A strong sub-surface northward flow of this water was apparent from the wire angles at stations close to the coast at 35° West.

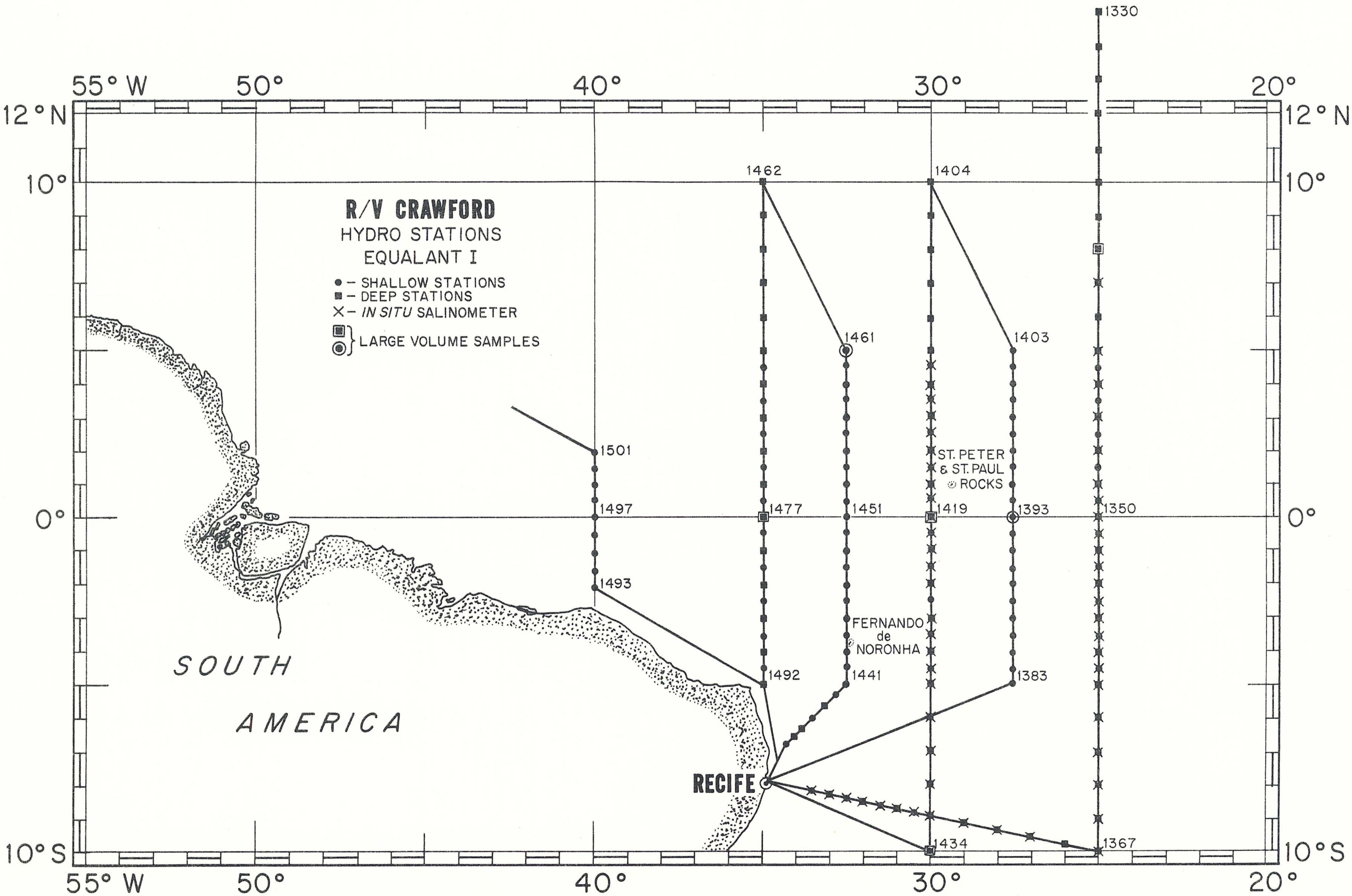

Figure 2. R/V CRAWFORD, hydro stations during EQUALANT I.

In addition, a relatively high salinity core was seen north of the Equator which may be associated with the Equatorial Counter Current. Another, though less striking, core was noticed south of the Equator; it also needs further study. Figures 3 and 4 show temperature and salinity profiles of the shallow layers of three of the sections.

The current meter data have been spot-checked and indicate that the current flow was easterly near the Equator at most stations. There are a few anomalies which have not yet been explained.

It is hoped that within two years another cruise can be made, extending the survey to the west of the present study. Problems having to do with the source of the high salinity water of the Equatorial Counter Current and the path of this water feeding into the Undercurrent should be pursued.

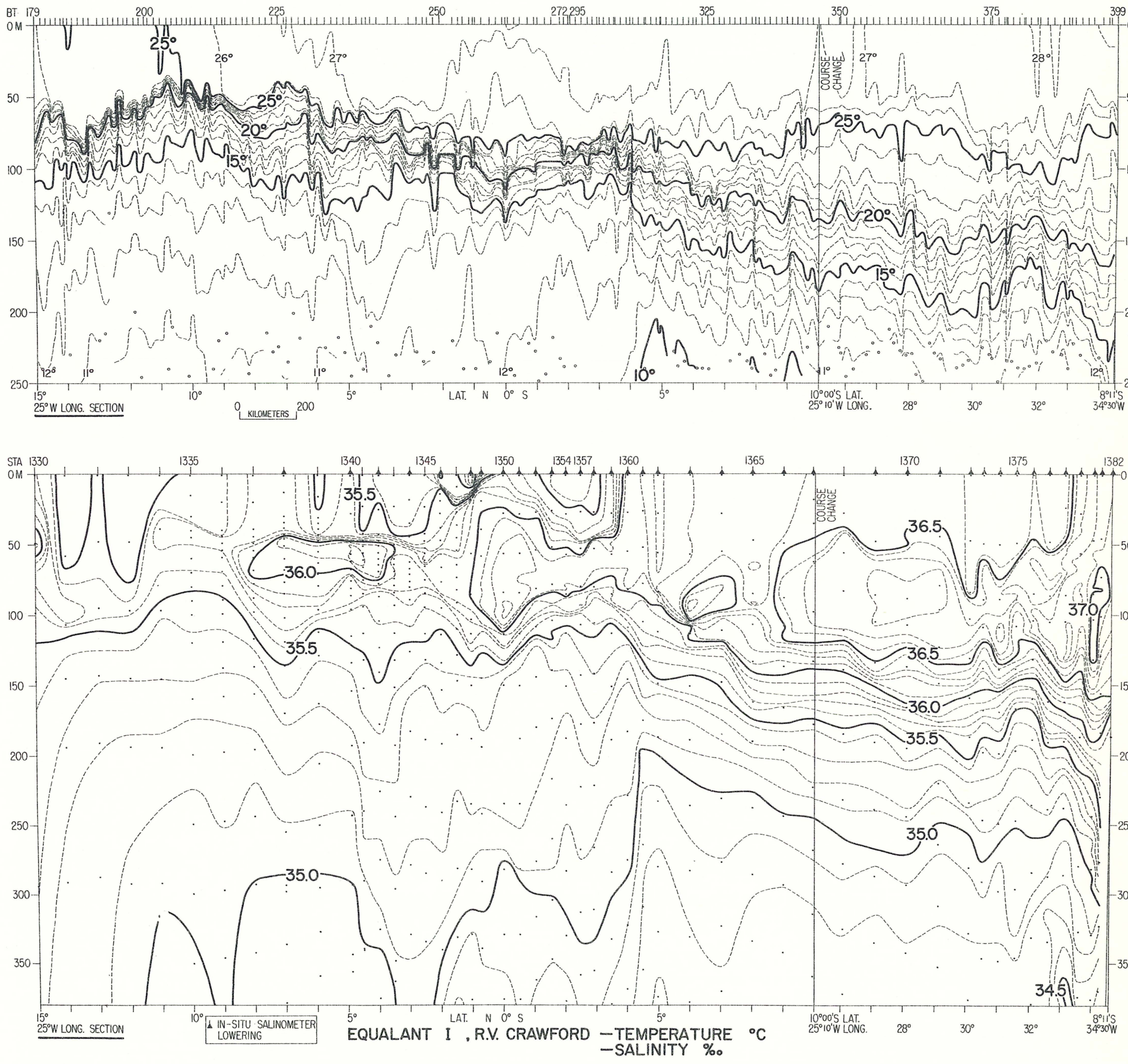

Figure 3. Temperature and salinity profiles, R/V CRAWFORD, EQUALANT I.

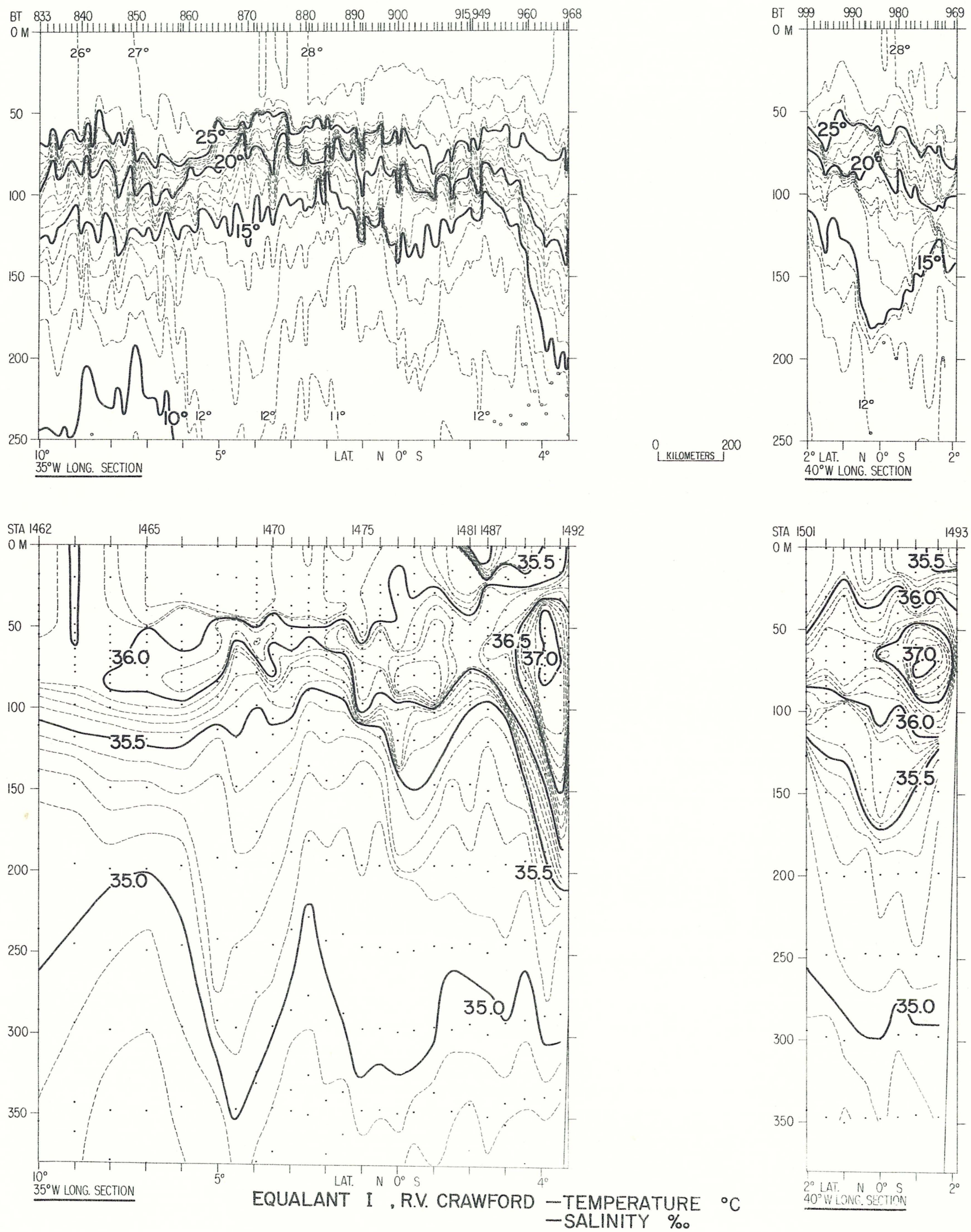

Figure 4. Temperature and salinity profiles, R/V CRAWFORD, EQUALANT I.

DEEP CURRENT MEASUREMENTS - Joseph R. Barrett

The possibility that the southward-moving water offshore from the Florida Current and the westward drift of the deep slope water inshore from the Gulf Stream are parts of a continuous deep current has been the subject of our investigations. The notion of continuity required that this current pass under the Gulf Stream somewhere in the vicinity of Cape Hatteras. It was proposed to measure the deep current using neutrally-buoyant floats along the axis of the surface stream as it was beginning to flow over the continental slope and into the deeper water of the western basin after leaving the Blake Plateau.

From September 30 to October 27, 1962, ATLANTIS was engaged in investigating these deep currents and a deep flow of southward-moving water was located. The ATLANTIS tracked neutrally-buoyant floats at five locations under the axis of the stream starting near 34° N and thence to the northeast at intervals of about forty km. Two or more floats were followed simultaneously at various depths at each location for about 2 days.

The volume of flow computed was 5 - 10 million m^3/sec, very much the same as computed by Swallow and Worthington from previous observations slightly further south. The data from this effort are now in the final stages of analysis. Deep current studies will be continued in the fall of 1963 in a cruise to the region east of the Blake Plateau and Blake Outer Ridge.

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VOLUME TRANSPORT OF THE FLORIDA CURRENT - Bruce A. Warren

Downstream from the Straits of Florida, the Florida Current increases severalfold in volume; however, the vertical shear of this additional flow is compatible only in part with geostrophic inflow from the Sargasso Sea. Although insufficient current observations preclude direct estimates of the volume of flow, the vertical shear of geostrophic velocity is specified by horizontal density gradients, and this imposes stringent limits on the possible distributions of the flow. Since flow is expected approximately along σ_t-surfaces--except near the sea surface--an inquiry into the sources of the additional flow is being undertaken by computing under various assumptions the flow across several oceanographic sections in the Florida Current and Sargasso Sea between selected σ_t-surfaces.

As a preliminary result it appears that the downstream pressure gradient on the inshore side of the Current between the Straits of Florida and Cape Hatteras is about twice as great as that on the offshore side, and this suggests a significant inflow to the Current from the slope water. This possibility is consistent with the large westward motions observed in the slope water by Volkmann (1962), and with the characteristics of deep water in the Gulf Stream which seems to flow in the same direction as the surface current (Fuglister, in press). In the temperature range where deep slope water is easily distinguishable from Sargasso Sea water (about 3.5 - 4.5°C), the water in the density gradients associated with the Stream has salinities much closer to those of slope water than of Sargasso Sea water.

It is hoped that this possibility can be investigated in detail, with particular reference to devising a scheme of geostrophic volume transports between σ_t-surfaces consistent with observed horizontal density gradients.

A paper has been accepted for publication in Tellus in which the large-scale meanders of the Gulf Stream, previously thought associated with a hydrodynamical instability, are related to the sloping topography of the Continental Rise (Warren, 1963).

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SALINITY MEASUREMENTS - Karl E. Schleicher and Alvin L. Bradshaw

During the past nine years the conductivity method of determining the salinity of sea water has come into general use. Prior to 1954 one of the few groups, if not the only one, that used a precision conductivity bridge for the routine determination of salinity at sea or ashore was the Coast Guard Ice Patrol stationed at Woods Hole. Today it is safe to say that almost all laboratories that are concerned with Physical Oceanography in this country and many in other countries have replaced or are replacing the Knudsen titration measurements with measurements made on various types of conductivity or salinity bridges. Salinity bridges can yield measurements almost an order of magnitude better in accuracy than those done by routine Knudsen titration and are very readily adapted for use at sea. These advantages have proved very significant in, among other ways, the ability to trace bodies of water by use of the temperature/salinity correlation and in the rapidity of processing data accumulated on a hydrographic cruise.

In more recent years, effort has been put into adapting the conductivity method to precision *in situ* measurements to great depths. Various *in situ* salinometers have been used for some time (including the so-called "STD" (Salinity Temperature and Depth Recorder) used at Woods Hole for many years) but these instruments were usable only to shallow depths and were of relatively low accuracy. The present attempts are to design instruments to go to 6,000 meters or deeper and to give salinities to an accuracy of $\pm$ 0.05 $^{o}/oo$ or better. Though the accuracy of an *in situ* salinometer may not compete with those of a laboratory-type salinometer for several years to come, the fact that the measurements are continuous can add considerably to the knowledge of the salinity and temperature structure of the ocean.

The work done by this group deals primarily with the design, construction and maintenance of instruments to measure the salinity of sea water by the conductivity method, but it also includes the measurement of the effects on conductivity of other properties of sea water besides salinity and temperature. One such property which enters the conductivity function when *in situ* measurements are made is pressure.

The Woods Hole Oceanographic Institution *in situ* salinometer was used on three cruises during the past year: A student cruise on the R/V CHAIN in July 1962 when 8 lowerings were made; R/V CRAWFORD Cruise 88 in October when 29 lowerings were made, and R/V CRAWFORD Cruise 91 with about 60 lowerings. The results from CRAWFORD 88 indicated that the depth circuit and the compensating cell were not functioning properly. However, the instrument was scheduled to go on the EQUALANT Cruise the following January where it was felt it would be extremely useful in helping to define the location of the equatorial undercurrent. The depth circuit was modified to accommodate lowerings only to 375 meters and some new cells were made which it was hoped would function well enough to this depth. With these modifications the instrument was used very successfully for half the cruise until electronic difficulties prevented further use.

The accompanying illustration (Figure 5) shows a series of Nansen bottle salinity points superimposed upon a smoothed tracing of the original depth-salinity curve as it appeared on the X-Y plotter. The tracing has been slightly shifted until the best fit of the Nansen points has been effected. This need of shifting the curve for the best fit indicates that the calibration of the instrument was not constant with depth which might be due to imperfect compensation by the compensating cell. This illustration does show, however, how useful the instrument can be in interpolating between Nansen bottle points even though its absolute accuracy may still not be satisfactory.

The investigation of the effect of pressure on conductivity was completed during the year. Measurements were carried out on sea waters of 31, 35 and 39°/oo at 5°C intervals from 0° to 25°C over a pressure range of 15 to 15,000 lbs. per square inch. A formula giving the percentage increase in conductivity with pressure as a function of pressure, temperature and salinity has been constructed which fits the measured values to within the equivalent of $\pm$ 0.007°/oo salinity units. The accuracy of the measurements is estimated to be $\pm$ 0.01°/oo or better.

For the coming year it is expected that some improvements will be made on the laboratory-type salinometers to improve their stability and decrease maintenance time. This includes transistorizing the present electronic circuits with an increase of the operating frequency from 1,000 cycles per second to 5,000 cycles per second, and the changing of the present resistance bridge to a transformer bridge.

The difficulties encountered with the *in situ* salinometer has lead to a reappraisal of the instrument as a whole. Serious thought is being given to changing it into a conductivity-temperature-depth probe and calculating the salinity on the surface rather than making compensations in the probe. Analysis of this problem is still underway but the first indications are that this system might have several advantages over the present instrument.

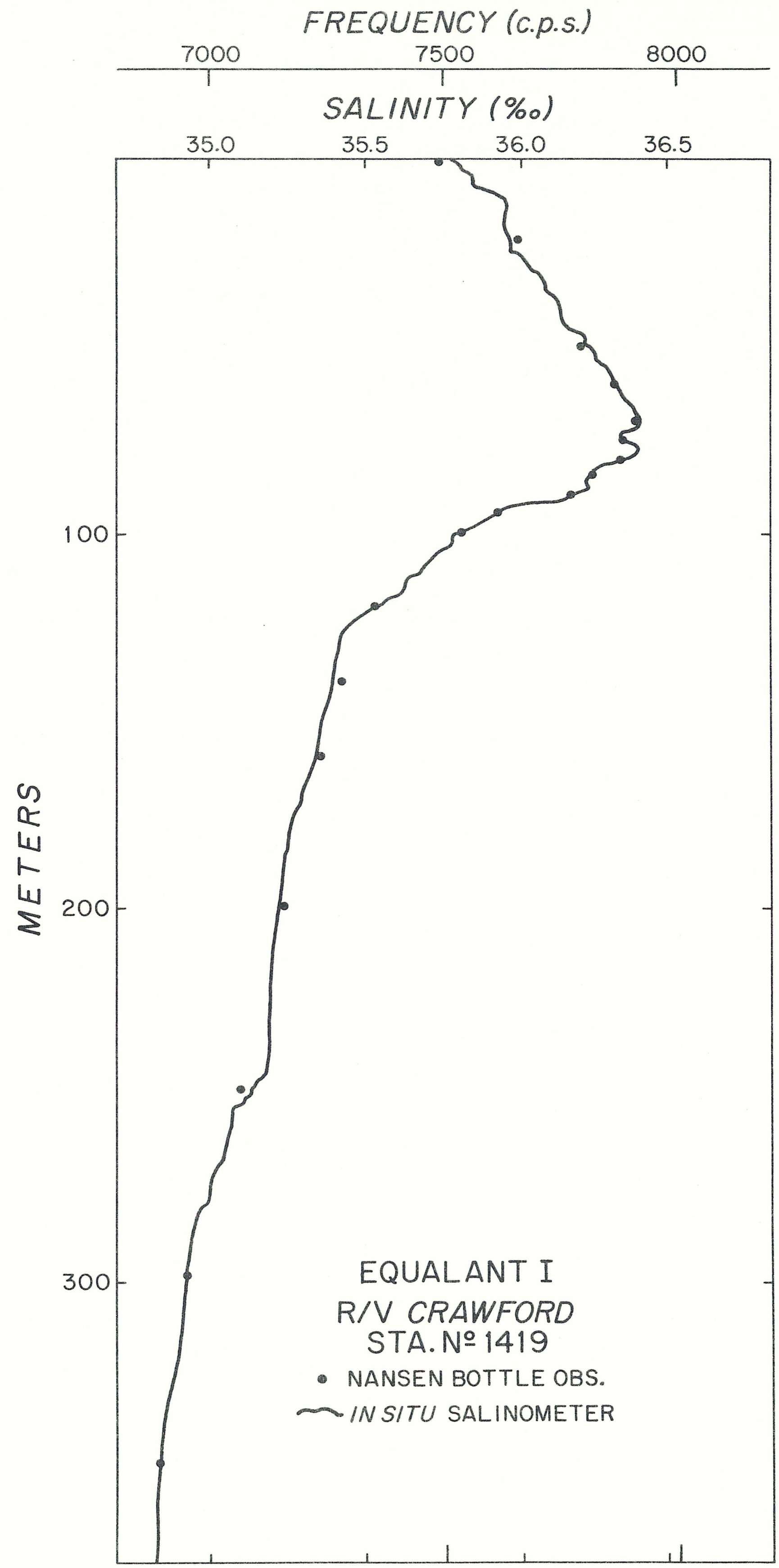

Figure 5. In situ salinometer and Nansen bottle salinity comparison, R/V CRAWFORD, EQUALANT I.

FORECASTING WINTER TEMPERATURES - Joseph Chase

The forecasting of winter temperatures at Woods Hole was started by Dr. Franz Baur's work on a relationship between November pressures and temperatures at selected stations and the subsequent average winter (December, January and February) temperature in southern New England. The availability of monthly mean pressure maps at the Institution made possible the examination of the pressure field for the entire hemisphere month by month. The examination revealed the similarity (allowing for normal seasonal changes) between the patterns of November and those of subsequent winter months. The similarities were found to be closer in high latitudes and especially along the trans-arctic ridge, the path which connects Siberia, the wintertime cold pole in this hemisphere, with the United States. It is down this path that our coldest air masses travel and the stronger the flow of cold air the colder the winter will be.

A template was devised to gauge the cold air flow in November and its readings are translated into average winter temperatures by means of a regression equation derived from experimental data. The method gave a correlation coefficient of +0.77 when applied to twenty years of independent data and this is significant at above the 0.1% level.

The forecast of average temperature for the past winter was 29.4°F, or 1.8°F below the normal currently in use by the U.S. Weather Bureau. The observed figure was 27.6°F giving an error of 1.8°F which is well within normal expectations.

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ATLANTIC THERMOHALINE DATA - Elizabeth Schroeder

(1) Processing of Bathythermograph Data. Table I in Section VIII of this report shows the source of bathythermograph slides received during the last fiscal year. In processing, the slides are read and photographed, the pertinent data transcribed, and ozalid prints are made. The statistics related to the processing are as follows:

BT slides received	6,565
BT slides photographed	5,737
Ozalid prints completed	18,575
Backlog of slides to be photographed	495

The daily lowerings by eleven lightships stationed along the eastern seaboard continue to be the nucleus of the processing done by this section. In January, 1963, the decision was made to process all data using the centigrade-metric units of measurements. This entails converting all the temperatures in our average books and is a long process which may take several years to complete.

During this period 5,961 bathythermograms were examined and from each the following information was recorded whenever it could be obtained:

Temperature at the surface
Temperature at 9M, 15M, 30M, 46M, 76M, 100M, 150M, 200M, and 250M.

As part of the associated activities carried on by this department, 159 BT reading grids were made for instruments calibrated here at the Institution. In conjunction with this was the mounting of grids to be issued to Institution personnel for use on cruises or to be sent to various institutions for use in their work. In the year just ended, 218 mounted grids and 33 spares were issued.

During the year, 13,578 bathythermograms and 4,162 hydrographic statipns were averaged and filed by one degree quadrangles, This leaves a backlog of 1,100 BT prints and 285 stations to be averaged. Of the prints averaged, 5,253 were from the National Oceanographic Data Center and 2,236 were from the Atlantic Oceanographic Group. These must all be read for temperatures at standard depths and since January, these temperatures must be converted to centigrade degrees before they can be averaged.

The geographical file now contains:

482,761	BT observations.
95,354	Hydrographic stations.
10,603	Surface data cards.
2,989	Mean surface data cards.
591,707	

(2) Variations of Temperature in the North Atlantic. A series of monthly average temperature profiles along eight meridians across the North Atlantic has been completed and is being prepared for publication.

"Average 200 Meter Temperature of the North Atlantic Ocean" was published in March, 1963 by the American Geographical Society as Folio 2 of the Serial Atlas of the Marine Environment.

Three hundred and eighty-four drawings have been completed for Atlantic coast average surface temperature animation and photography will be started as soon as modification of a light table is finished. When the movie is completed, a paper including the monthly average surface temperature charts on which the film is based will be submitted for publication.

(3) Data from Publications and other Sources. Five hundred and four Hydrographic stations were copied from foreign International Geophysical Year data. This makes a total of 5,364 stations which have been copied and completes all International Geophysical Year data received to date. These data have not been averaged or filed, but are being held for evaluation and analysis. In addition to these, there were 388 stations copied from reduced data for various cruises and 3,380 were copied from publications.

(4) PANULIRUS Station Data. Twenty-seven PANULIRUS stations, #154 through #180, were corrected, sigma-t computed, temperature, salinity, and oxygen curves were drawn, and all stations were added to existing temperature, salinity, and oxygen profiles. A correction graph was drawn for one protected thermometer. Reduced data and geographical file cards were copied for all stations. Some of the early stations were made as part of a training program for biologists taking part in the International Indian Ocean cruise.

Note: The PANULIRUS is the research vessel operated by the Bermuda Biological Station.

INTERNAL WAVES - Arthur D. Voorhis

During the past year studies were made of internal wave data which had been collected the previous year on a cruise of the R/V CHAIN to the Mediterranean Sea. First, an attempt was made to compute the spatial power spectrum of internal waves observed in an area to the east of the Island of Madeira. The waves were detected at a depth of 70 meters beneath the oceanic wind mixed layer, by recording continuously the variations of temperature from one of the thermistors mounted in the towed thermistor chain as the ship steamed at a speed of 11 knots along various headings. On each heading the temperature variations were sampled over a distance of about 10 kilometers. During each run these variations were also recorded on magnetic tape as a frequency-modulated signal in such a format that power spectra could be easily computed using the Addressor program with the Recomp II computer at Woods Hole. About ten spectra have been computed from this data and in all cases show that the internal wave power increases with wave length from the minimum resolvable wave length of about 100 meters to the maximum resolvable length of about 1,000 meters. No spectral peaks were found within these limits. In order to find such peaks, measurements would have to be made over considerably longer horizontal distances in order to resolve the spectra at longer wave lengths.

The second study made was of the large tidally-driven internal waves observed in the Straits of Gibraltar. These waves propogate along the large density gradient between Atlantic water at the surface and the heavier, more saline Mediterranean water lying beneath. This study was done in cooperation with R. Frassetto, now at the NATO Laboratories in La Spezia, Italy, who has been interested in these waves for several years. From the pressure recorded from several pitotmeters mounted in the thermistor chain, it was possible to measure, while the ship was underway, the water velocities associated with these large waves and in some cases it was observed to be as high as 100 cm/sec.

II. THEORETICAL OCEANOGRAPHY

DYNAMICS OF OCEAN CURRENTS - Nicholas P. Fofonoff

Three problems related to steady flows in the simple homogeneous and two-layer oceans were examined during the past year. In two of these problems, the vorticity equation was studied to determine the effects of bottom topography and side boundaries in deflecting and intensifying the flow. The third problem was related to the decay of relative vorticity in steady unbounded flow. An exact two-dimensional solution has been found that incorporates both driving forces and friction. Its characteristics are being examined further.

In recent months, a considerable amount of analysis has been conducted on the current data obtained from the Richardson Current Meters. This effort will be implemented and continued.

HYDRODYNAMICAL MODEL STUDIES - Alan J. Faller

The rotating basin, which was completed in the spring of 1962, was used during the past year to study the effects of wind stress on the rotating water mass, the thermal convection processes in a rotating system and the instability of laminar boundary layers in rotating systems.

In conjunction with the laboratory measurements of the instability of the laminar Ekman boundary layer, the following proposal was made: that the Langmuir circulation cells in the ocean are a manifestation of the instability of the spiral boundary layer near the surface of the ocean. To test this hypothesis, measurements of the angle between the surface wind and the directions of the wind rows were attempted. In some cases these observations were made from a small boat and in other cases these angles were observed by scattering papers over the surface of the ocean to indicate the wind rows and by using smoke flares to show the surface wind direction. In all cases the observations indicated that the wind direction was to the left of the row direction; this was in agreement with the theoretical prediction. The analogy between the laboratory results and the Langmuir cells was presented at the meetings of the American Geophysical Union in Washington, D. C., April 1962.

A paper entitled "The Instability of the Laminar Ekman Boundary Layer and Its Application in Geophysical Fluid Dynamics" was presented at the joint symposium of the American Meteorological Society and the American Physical Union in Boulder, Colorado, September 1962. A manuscript entitled "An Experimental Study of the Instability of the Laminar Ekman Boundary Layer" was accepted for publication by the *Journal of Fluid Mechanics*.

BUOYANT CONVECTION - Peter M. Saunders

Studies of buoyant convection have been continued with particular emphasis on the nature of the turbulent exchange between the buoyant fluid and its environment. To extend the range of these studies a new shallow tank has been constructed. In these experiments a cylindrical column of dense fluid will be released within a shallow tank of water. It is expected that the flow of this dense fluid will have certain similarities with turbidity currents and with thunderstorm downdraughts thereby leading to a better understanding of these phenomena.

III. APPLIED OCEANOGRAPHY

UNDERWATER PHOTOGRAPHY - David M. Owen

The underwater photography and self-contained diving work at the Institution is primarily concerned with the development of underwater camera equipment both deep-sea and hand-held, the use of underwater cameras as a supplementary tool applied to some of the research problems at the Institution, and the development and supervision of the self-contained diving activities at the Institution.

Bottom photography was accomplished on three cruises of the R/V BEAR, one cruise of the R/V ASTERIAS, and one of the R/V ATLANTIS. R/V ASTERIAS and R/V BEAR cruises took place in the Narragansett Bay region and the continental shelf south of Cape Cod. The Robot stereoscopic camera was used to photograph small scale roughness and the various bottom types sampled, and the results will be correlated with the echo strength and bottom reflectivity measurements taken by Lloyd F. Breslau and Andrew Nalwalk. Self-contained diving was also employed in Narragansett Bay as an aid to the bottom studies, and the recently developed portable underwater tape recorder proved of value in recording the divers' observations.

Close-up slow-motion pictures were made of wave-induced sediment movement for Dr. John M. Zeigler on Cape Cod and Carribean beaches. The camera setup for this study has become more sophisticated in that wave height, velocity, time, and digital counter (for "locking in" with recordings made on the beach) are shown in the same picture with the shifting sand particles.

A camera and strobe flash unit was attached inside a large Campbell Grab (bottom dredge) which will be used by Dr. K. O. Emery of the Institution in the geological study of the Atlantic continental shelf and slope which is being sponsored by the United States Geological Survey. This camera, a 35mm Robot, photographs the undisturbed sediment before the Grab closes.

It is anticipated that work in the near future will include further collaboration with Mr. Breslau in bottom reflectivity studies and with Dr. Zeigler in the study of wave-induced sediment movement. In addition, deep-sea camera work is planned with Dr. Zeigler in the Carribean area.

Deep-sea bottom photos made during R/V BEAR Cruise 258 in December 1960 , a bathymetric and sediment survey of the Tongue of the Ocean, Bahamas, appear in a report (Woods Hole Oceanographic Institution Reference No. 62-27) submitted by Mr. William D. Athearn in July 1962, to the United States Naval Underwater Ordnance Station, Newport, Rhode Island.

BUOY TELEMETRY - Robert G. Walden

Long range telemetering buoys have been developed during 1962 and 1963. Successful tests have been made of buoys which telemeter, on command, a variety of data in digital form over ranges of 1000 miles.

In December 1962 a deep current telemetry station was set at 32° 10'N 64° 30' W. The buoy was interrogated from the shore and several hundred recordings were made of scheduled information. These transmissions were monitored by International Telephone and Telegraph at Southampton, Long Island with excellent results.

A telemetry receiving and interrogation station has been built at Waquoit, Massachusetts, to provide a good receiving and transmitting evniroment.

COMPUTER APPLICATIONS - Duncan E. Morrill

In the summer of 1962 the Institution began assembling the nucleus of a computing group as a first step in significantly upgrading its capabilities in the field of rapid data processing. An early task was the selection of an appropriate computing system for the Institution. A General Electric GE225 was selected after a careful analysis of cost versus work capability of several leading systems.

In April 1963, the GE225 was installed on a temporary basis in the Laboratory of Oceanography; this provided better preparation for the eventual use of the entire system. In June the initial part of the GE225 was moved to the Laboratory of Marine Sciences; the rest of the system was delivered; and the entire system set up in the new Information Processing Center.

The GE225 is an intermediate size computer; the Institution's configuration, a rather large one. This gives a very flexible system at modest cost. It has card input and output, high-speed printing, magnetic tape units, paper tape input and output, disc storage and a special communications unit for the attaching of special input and output equipment, e.g., analog to digital converter and graph plotter.

The major applications will be data reduction, statistical analysis, station data processing and time series analysis, and simulation. It is anticipated that with learning and experience there will develop very rapidly many other types of applications and that computing will become a valuable and essential element in the Institution's work.

IV. MARINE BIOLOGY

PHYTOPLANKTON, PHOTOSYNTHESIS AND BIOLUMINESCENCE - Charles S. Yentsch

In temperate oceans, surface enrichment with plant nutrients from deep water occurs as a result of a seasonal overturn which is accomplished by a cooling of the surface layers and mixing by wind action. In tropical oceans, which are seasonally stratified, the steady low level of photosynthesis is presumably maintained by biochemical regeneration and diffusion; however, neither process can be easily demonstrated.

On R/V CHAIN Cruise 26 the rate of phytoplankton production was examined in areas where horizontal water mass transport was extensive. Observations showed that extremely high production occurred in areas where sigma-t surfaces were diverted towards the surface presumably as a result of geostrophic flow. In the northern hemisphere the area of high production is to the right of the observer looking directly into the current. At first glance it would appear that this process was identical to that observed in coastal upwelling. However, the magnitude of the production encountered could not be accounted for on the basis of wind stress considerations. The augmented production in this portion is undoubtedly the result of higher density, nutrient rich water being placed in a closer proximity to the surface. There is also the suggestion that an upward displacement of water is occurring, presumably along the sigma-t surface. However, this may merely be a reflection of a general mixing process along the region of the thermocline.

The importance of this process in the total photosynthetic production in the oceans has yet to be ascertained. However, it is clearly evident that in many areas previously thought of in terms of biochemical and diffusive regenerative processes, the horizontal invective process is important in the enrichment of surface waters. We are presently considering the relationship between current velocity and surface production.

Cycles of photosynthesis and bioluminescence have been observed in cultures of marine phytoplankton. Moreover, daily changes in both processes are observed in surface waters of the open ocean. The causes of the photosynthetic periodicity are obscure but seemingly are the result of a fatigue of the photosynthetic process after intense periods of photosynthesis. It has been shown that the daily cycle of bioluminescence is the exact opposite of the trend of solar radiation. Culture experiments have shown that the bioluminescence illuminating process is inhibited by bright light. The daily change of bioluminescence can be observed throughout the euphotic zone. The depth at which radiation does not influence bioluminescence is approximately 125 meters in the open ocean. In more turbid coastal waters this depth is much shallower. Our observations of the vertical change of bioluminescence show that these changes are not measurably influenced by vertical migration of organisms. Furthermore, a process of adaptation of the organisms occurs at different depths. This results in deep water organisms being more sensitive to smaller light intensities than surface organisms.

A highly sensitive and precise method for the measurement of chlorophyll and phaeophytin by flourescence has been devised. Measurements of the concentrations of these pigments are being made daily in Woods Hole waters. Generally, the phaeophytin concentration is quite low, but after a winter gale the concentration of this pigment has been observed to increase greatly. This is the result of plant detrital material being stirred upward from the bottom. Measurements of pigment in bottom deposits have shown that phaeophytin concentrations are quite large there. Observations in the open ocean have shown that the phaeophytin concentration is very low within the euphotic layer. Below this layer all the chloroplastic pigment appears to be in the phaeophytin form. The other site for high concentrations of phaeophytin appears to be in the intestines of herbivorous crustaceans. Coarse net tows, when extracted with acetone, yield considerable greenish pigment. Measurements show that practically all of this is phaeophytin. Factors affecting the formation of phaeophytin in phytoplankton have been studied using cultures. These observations show that when nutrient-deficient, the chlorophyll a does not convert to phaeophytin, even when the culture is incapable of photosynthesizing.

Factors affecting the compensation intensity (photosynthesis: respiration) are being studied using cultures of marine phytoplankton. A culturing apparatus has been designed where phytoplankton population is retained on a membrane filter. This allows the removal or addition of new culture medium without changing the population number. The chamber may be equipped with oxygen or pH electrode, and as the culture per unit volume is low in the chamber photosynthesis or pH responses are quite rapid. These experiments show that as a culture becomes progressively nutrient-deficient, the compensation intensity increases. In most healthy cultures the compensation intensity is about 1/10th the intensity for saturation of photosynthesis. Extremely low compensation intensities have been obtained at temperatures lower than are considered optimal for growth.

Interest in development of more satisfactory and dependable opening closing units for plankton sampling has led to the development of a pressure-operated unit. Actuation is accomplished by a microswitch which is closed by a pressure piston. The closing of the switch energizes an explosive wedge which allows a spring-loaded damper to open the mouth of the net. The damper closes the net at the same depth by a latching relay and a second exploding wedge. Sea trials have been extremely successful and have demonstrated a second desirable feature, the noise of the small underwater explosion which is audible to a conventional submarine hydrophone, and thus signals the operation of the unit.

NUTRIENT CHEMISTRY - David A. McGill and Nathaniel Corwin

Of the elements in sea water necessary to support the biomass, phosphorus is usually the one available in the most limited amount. The element is utilized by organisms mainly in the form of inorganic phosphate in the euphotic zone. Regeneration of the element from particulate and dissolved organic phases can occur throughout the water column. It is standard practice at this laboratory to survey the entire water column for the total phosphorus content as well as the inorganic phosphate level. From the difference of these determinations a measure of the organic phosphorus level is obtained and some interpretation of the various stages in the phosphorus cycle can be made. Our data indicate that there is about twice as much organic phosphorus at deep-water levels of the South Atlantic as is found north of the Equator, which in turn suggests that the productivity of the South Atlantic may be accordingly higher.

Since the overturn of water in the area north of Newfoundland contributes most of the North Atlantic deep-water circulation, this area is particularly important. From two recent expeditions in the waters between Labrador and Greenland and from an expedition in August to Baffin Bay we have obtained approximately a thousand samples. It is hoped that studies of the completed data can be tied to the observations available from further south, where previous data have shown some penetration of high organic phosphorus in deep water which has been ascribed to a northern origin. Charts of the total phosphorus distribution are being prepared; for much of the Atlantic basin and particularly the most northern region, these data are now available for the first time.

Considerable time is also spent on comparison of analytical procedures and techniques. In July 1962, D. A. McGill spent ten days on the Russian research vessel VITIAZ, operating out of Perth, Australia, as part of a UNESCO-sponsored project for inter-comparison of analytical work. Oxygen determinations and phosphate methods were compared on board by Australian, Russian, Japanese and American personnel. An inter-comparison of techniques of oxygen measurement among the major U. S. laboratories was held in Woods Hole in December 1962. The level of oxygen saturation is now being investigated, since preliminary observations suggest that the present literature overestimates the oxygen saturation due to an underevaluation of the Bunsen coefficient.

A report presented at the first SCOR/UNESCO Intercalibration Conference, held at Honolulu, Hawaii, September, 1961, entitled "An Intercalibration of Analytical Techniques in Oceanography" by Bostwick H. Ketchum and David A. McGill has been prepared in manuscript for submission to UNESCO and publication through the Special Committee on Ocean Research.

V. CHEMICAL OCEANOGRAPHY AND MARINE GEOLOGY

INORGANIC CHEMISTRY - Vaughan T. Bowen

Surface samples for studies on the fission products from fallout have been collected on a biweekly schedule from the four Atlantic U. S. manned weather ships. Study of yttrium 91, cerium 144 and promethium 147 in relation to the weather data has elegantly supported our thesis that fallout delivery over the ocean is mediated in different ways from that over the land. The ratio of recent to pre-1961 fallout may be only about half that over land. Especially within the Bermuda-Azores high pressure cell, very large amounts of fallout, especially low in recent material, appear to have been delivered almost in the absence of sensible precipitation. When winds in excess of about 38 mph are reported the samples show strong evidence of dilution by water which is low in both new and old lathanide fission products. This would, of course, not be observed in the situation postulated by some oceanographers, of an upper wind-mixed layer essentially out of communication with the underlying water.

Substantial completion of the analyses on the deep stations taken during CHAIN Cruise 17 in 1961, has shown very similar patterns at stations at 0°, 5°N, and 11°N. Surface Sr^{90} concentrations are identical and values at 100 to 300 m are slightly elevated in the northern stations compared to the equatorial values. Values for deep samples, down to 2500 m, at both 11°N and 0°, are essentially the same. The values at intermediate depth on the equator are only very slightly elevated over those observed in 1958, and are much less than those at 29°15'N in the southeastern Sargasso Sea where the surface water Sr^{90} is about doubled and the values at 100 m and 300 m are more than doubled. At present this seems another indication of the especially high delivery of fallout under the Bermuda-Azores High.

Preliminary study of our data from the Chukchi Sea does not support the Russian idea of very considerable transport of Pacific surface water through this shallow sea northward into the Arctic Ocean. The fission product analyses are all consistent with the view that this is an essentially stagnant area, with most of the fallout Sr^{90} delivered to it still in its own waters, and most of the $cerium^{144}$ already in the sediments.

Our program of analysis of trace elements in pure species collections of plankton continues to be fruitful. A major publication of results is in preparation and collection of samples has been accelerated. From data in hand, two interesting studies have been made: Lithium: Rubidium ratios permit dividing our specimens into two groups - one with ratios greater than 1, and mostly much greater, and one with ratios less than 0.4. By contrast only two collections fall in the range of sea water (Li:Rb 0.85) and one of these, being a two-species composite, is questionable. Chow and Goldberg have recently published several profiles of Li concentration with depth, all showing the minimum Li:Cl ratio at surface; this is not emphasized in their discussion.

In fact, however, the activities of both groups of plankton cited above would tend precisely to this effect, since the Li acceptors are in general creatures which withdraw Li from surface waters and the Li rejectors are in general predators which may be thought to excrete more intensively at depth.

Our series of Sr:Ba ratios in plankton also point to the possiblity of biological control of the barium concentration profile in the oceans. Goldberg has already postulated this must be the major avenue of removal of Ba from surface waters. We find, contrasted to a sea-water Sr:Ba ratio about 900, that all our plankton ratios are lower: the highest about 300, the mean well below 200 and the lowest 10. It should be possible by accumulation of more analyses and by culture experiments already begun, to test Goldberg's hypothesis that return to the water column is from sinking dead organisms or fecal material and is controlled by the solubility of barium sulfate. It also appears certain to us that any biological uptake system showing strong Ba to Sr discrimination will show even stronger change, in the same direction, in the Ra:Sr ratio. Instrumentation is about completed to use solid-state alpha spectrometry for radium analysis in organisms to test this hypothesis; and autoradiographic examination of plankton tissues is also underway to explore this.

A major activity of our program in inorganic marine geochemistry during the past year has been organization of our two-ship cruise to the Equatorial Atlantic. As is known, our program was begun and has been carried through independently of the International Cooperation Program, EQUALANT, which appears to have been sparked by our example. Much of our work will, however, mesh well with the more diffuse program, and their results should expand our interpretation of our own studies.

ORGANIC GEOCHEMISTRY - Max Blumer

Hydrocarbons are more refractory than most organic compounds which are introduced into the sea water by organisms, by pollution or from sedimentary and terrestrial sources. Their residence time in the ocean should be sufficient to permit their use for the characterization of lateral and vertical movements of water masses. The biological and geochemical sources of the marine hydrocarbons and their concentrations in the sea water have been studied to gain a better understanding of their origin, their steady state concentration and their eventual fate. The processes governing the transformation of organic compounds in marine sediments have been observed indirectly by an analysis of the stepwise transformation of molecules of known origin and structure in the subsurface.

During the past year an organic-free water sampler which can be triggered at a depth to filter a 5 gallon water sample has been constructed and tested. In situ filtration by a clean sampler is particularly important to avoid contamination by the ubiquitous hydrocarbons of fuel and lubricating oils.

Two techniques have been developed for the recovery of the dissolved hydrocarbon fraction of sea water. Extraction in a stabilized solvent bed followed by concentration of the extracts by zone melting gives good recovery over a wide boiling range; a simplified technique, using low temperature evaporation of the solvent, permits a much more rapid workup under retention of the higher boiling fractions of the extracts.

Conditions have been defined for a separation of the extracts into hydrocarbon-type concentrates by small-scale chromatography and clathrateformation. Further separation by gas chromatography and the recovery of gas chromatographic fractions for infrared or mass-spectral analysis is now possible.

Using these techniques, all straight chain hydrocarbons from pentadecane to dotriacontane have been identified in near shore waters. In the aromatic fraction, fluoranthene and pyrene have been identified by several independent techniques.

A study of the hydrocarbons in zooplankton from the Gulf of Maine has let to interesting results. Copepods of the Genus Calanus contain up to several percent of pristane, a hydrocarbon which they synthesize from phytol contained in their phytoplankton diet. As a relatively inert compound the pristane is passed on throughout the marine food chain; it appears in small quantities in the liver oils of herring, sharks and whales and has also been isolated from petroleum. Other planktonic organisms contain much less or no pristane at all, though some appear to contain other hydrocarbons not found in Calanus. Thus, organisms of limited geographic occurrence may well be found to tag a water mass with a species-specific organic product, which - in the case of a hydrocarbon - may be retained in the water once it moves away from its origin.

Work has continued on the characterization of the aromatc hydrocarbons of a fossil sea lily. In addition to many hydrocarbons common to other sedimentary materials, several unusual hydrocarbons which had not been found in nature before have been identified. They are in direct chemical and genetic relationship to the pigments of the same fossil and their discovery permits conclusions about the organic transformation reactions occurring in the subsurface environment to which the fossil had been exposed.

SEDIMENTARY GEOLOGY - Richard M. Pratt

The overall objective of the sedimentary geology program is an understanding of the geologic history and structure of the ocean basins off the east coast of the United States. The accumulated sediment in the basins affords a record of the histroy of the basins, just as on land the history of a basin is recorded by the contained stratigraphic record. The process of sedimentation, the relationship between sediment types, and the bottom topography must be thoroughly understood if the sedimentary record is to be correctly analyzed.

A contour chart using 100 meter contours has been plotted from data collected off the east coast of the United States during numerous Institution cruises. This chart has been constructed with emphasis placed on abyssal plain gradients, channels and similar features that have a bearing on patterns of sediment distribution on the ocean floor.

Work has continued on a compilation of carbonate data and available bottom sample descriptions of the area. This material coupled with the chart data is being incorporated into a paper entitled "Sedimentary Enviroment off the East Coast."

Four trips have been made on the R/V GOSNOLD and one on the R/V ATLANTIS II in order to collect bottom samples and bathymetry from the area of interest on the east coast. More detailed field work is planned in the carbonate area off the Blake Plateau.

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R. M. Pratt, Great Meteor Seamount - Deep Sea Research, Vol. 10, pp. 17-25.

R. M. Pratt, Photographic auf dem Meeresgrund-Kosmos, Vol. 7, pp. 306-311

R. M. Pratt, Woods Hole Reference No. 63-14, Track Charts, Bathymetry and Location of Observations, Chain Cruise #28.

COASTAL STUDIES:

(a) SHELF SEDIMENTS AND MARINE CIRCULATION - John M. Zeigler and William D. Athearn

The interrelationship between the distribution of sediments and the circulation of the water in various shallow embayments is demonstrated by the distribution of the tests of pelagic Foraminifera in the sediments. Species from the open sea can be identified and their distribution in the bottom sediments is an indication, not only of the present-day circulation (surficial sediments), but also of whether circulation in the geological past was the same as at present (subsurface sediments).

In the past year a manuscript which deals with the distribution of Foraminifera and the intimate relationships between the hydrography and the type of rainy season in the general region of the Gulf of Venezuela has been completed and submitted for publication. Approximately ninety sediment samples collected from the Gulf of Darien (Uraba), Colombia, were studied for pelagic Foraminifera and it was found that although the more oceanic samples contained by far the greater abundance, occasional pelagic tests were found even near the head of the Gulf. Four short plankton tows were made in December 1962 from the Colombian vessel BOCAS DE CENIZA from the same gulf. Living pelagic Foraminifera were found only in samples from the entrance to the Gulf, but the omission from the other tows of even dead specimens may mean only that they are extremely rare or that the currents which have brought in those found in the sediments are seasonal and that our tows were made on an off season. It is interesting to note that species of pteropods, believed to be marine pelagic and found in deep-sea sediments, were found plentifully even at the station nearest head of the Gulf, both in the net tow (living when collected) and in the bottom sediments.

Sediments on the continental shelf south of Woods Hole are also being investigated for pelagic Foraminifera. Here again they are found in the sediments occasionally but have not been recorded from plankton hauls in the shallower shelf waters, perhaps also because of their relative scarcity, except when concentrated as dead shells in the sediments.

It is anticipated that more plankton tows will be made in the Gulf of Darien next winter with larger nets towed for longer periods at various points in the water column. Investigation of this general subject will continue whenever the opportunity arises to study bottom samples made available by our colleagues or whenever there is an opportunity to make more plankton net collections.

COASTAL STUDIES:

(b) COASTAL PHOTOGRAPHY - William D. Athearn and Claude Ronne

Of the various classes of landforms which make up the earth's surface, coastal features are, generally speaking, most susceptible to rapid change of shape and position. This is because the majority of coastal features are composed of unconsolidated and therefore comparatively easily moved sediments which are situated where wind, waves and currents may all contribute to their formation, modification or destruction. Storm waves are undoubtedly the single most important force in the rapid modification of a spit, bar or barrier island and are of course ineffective elsewhere than at approximately sea level. From a geologist's point of view it is appropriate to record these changes, some of which are quite temporary while others are more permanent, along the entire coastline not only because of the historical value of such records but also because evolutionary trends for various types of coastlines should become apparent as the records accumulate.

Time-lapse, oblique color movie photography of long sections of the coast from an aircraft has enabled us to record beach changes at relatively frequent intervals at a comparatively low cost. Starting in 1954, a dozen major flights have been made, most between Long Island and Charleston, South Carolina. Three have extended around the Gulf Coast to the Rio Grande. Several recent flights have included vertical photography. Both types of photography are valuable depending on the purpose for which the photos are intended. The oblique movies include much of the area behind the immediate beach and are of considerable interest from a standpoint of the economic evolution of the coastal area as well as from the aforementioned geological standpoint. The verticals are susceptible to measurement, and comparisons of amount of change may be made. Some of the flights have bracketed major coastal storms so that it has been possible to record their affects. Follow-up flights one-half year or so later have enabled us to record the amount of recovery the affected areas have made, or what permanent changes had been effected.

A short flight was made in July 1962 to bring up to date our coverage of the local beach area. Time-lapse movies were taken of the Outer Cape Cod beaches and those of Nantucket and Martha's Vineyard. Overlapping vertical black and white photographs were made of the Cape Cod Bay shoreline and of the Outer Cape beaches. In September we photographed between Long Island, New York and Cape Fear, North Carolina. We employed time-lapse photography between Montauk Point and Cape Charles, Virginia and then shifted to vertical photography for the Outer Banks area of North Carolina. This operation was a follow-up for a similar flight made in April 1962 subsequent to the severe March northeast storm which had severely mauled much of the beach area of the east coast of the United States. Many scars remained and two or three new inlets (in the Chincoteague area of Virginia and one just north of Cape Hatteras) had not closed, but as would be expected, most indications were toward a general "healing" of the beach to pre-storm conditions.

In late December we presented a paper at the AAAS meetings in Philadelphia which dealt with changes at Cape Hatteras and Hatteras Inlet during the past 17 years, based on comparisons of our more recent vertical photographs and some earlier verticals provided by the U. S. Coast and Geodetic Survey. It was indicated that changes at Cape Hatteras may be of a cyclic nature while there is a definite southwesterly migration of Hatteras Inlet. This paper has been published in Naval Research Reviews.

A study of the affects of hurricane "Carla" on the Gulf Coast of Texas in 1961 and of the degree of permanent change or of recovery of the barrier beaches is partially completed. Results are expected to be submitted for publication in the coming year.

It is planned to continue the flights indefinitely, with about a two-year interval between complete coverages of the East and Gulf Coasts, but with occasional additional flights to specific areas in the event of severe storms. A flight from Maine to Texas is anticipated for the spring of 1964 to keep the series up to date.

References

Athearn, William D. and Claude Ronne, 1963 Shoreline changes at Cape Hatteras, <u>Naval Research Reviews</u>, Vol. XVI, No. 6, pp. 17-24.

VI. SHIP AND AIRCRAFT USE - John F. Pike

SHIP CRUISES SUPPORTED BY CONTRACT Nonr - 2196

Ship	Cruise	Dates	Chief Scientist	Area
R/V ATLANTIS	287	30 Sept.-27 Oct., 1962	Joseph Barrett	Gulf Stream
R/V BEAR	280	19 July-30 July, 1962	E. Bunce	Off North Carolina
R/V CHAIN	28	6 July-21 July, 1962	L.V. Worthington	Grand Banks
	35	23 Jan.-18 May, 1963	W. Richardson V. Bowen	Gulf Stream
R/V CRAWFORD	86	10 July-31 July, 1962	J. Ewing	Off North Carolina
	87	17 Sept.-19 Sept., 1962	F.C. Fuglister	Martha's Vineyard
	88	28 Sept.-27 Oct., 1962	Ferris Webster	Off Cape Hatteras
	91	17 Apr.-22 Apr., 1963	G. Metcalf	EQUALANT I
	93	4 June-22 June, 1963	A.Voorhis	Bermuda and Sargasso Sea
R/V ASTERIAS	-	Day Trips in Vineyard Sound		

AIRCRAFT USE SUPPORTED BY CONTRACT Nonr - 2196

R4D	Month	Hours	Major Users
	July, 1962	40.3	Parker
	Aug., 1962	33.2	Parker
	Sept., 1962	73.7	Parker, Athearn
	Oct., 1962	68.1	Parker
	Nov., 1962	48.2	Zeigler, Kraus
	Dec., 1962	0	
	Total	263.5	
Helio Carrier		80.0	Schevill

VII. PUBLICATIONS

PUBLISHED PAPERS	WHOI Contr. No.
Stern, Melvin A., The joint instability of hydro-magnetic fields which are separately stable and the self-maintained fluid dynamo. Physics of Fluids. 636-642.	1289
Hulburt, Edward M., The distribution of phytoplankton in coastal waters of Venezuela. Ecology 44(1): 169-171.	1303
Mead, Giles W., Observations on fishes caught over the anoxic waters of the Cariaco Trench, Venezuela. Deep-Sea Research 10(3): 251-257.	1310
Volkmann, G., Deep current observations in the western North Atlantic. Deep-Sea Research 9(5): 493-500.	1311
Steele, J.H., J.R. Barrett and L.V. Worthington, Deep currents south of Iceland. Deep-Sea Research 9(5): 465-474.	1317
Von Arx, William S., Measurement of subsurface currents by submarine. Deep-Sea Research 10(3): 189-194.	1325
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VIII. BATHYTHERMOGRAPH DATA

TABLE I

Bathythermograph Data Received at W.H.O.I. July 1-31, 1962

Cruise No.	Asc. No.	Area	Vessel	Observation Dates	No. of Slides
LS AMB 77	4096	On station	AMBROSE LIGHT-SHIP	V-22-62 V-31-62	10
LS NAN 76	4109	On station	NANTUCKET LIGHT-SHIP	V-3-62 V-31-62	29
LS SAV 78	4110	On station	SAVANNAH LIGHT-SHIP	VI-1-62 VI-30-62	30
LS BAR 79	4111	On station	BARNEGAT LIGHT-SHIP	VI-1-62 VI-30-62	30
LS DEL 17	4112	On station	DELAWARE LIGHT-SHIP	VI-1-62 VI-30-62	29
LS FFB 79	4113	On station	FIVE FATHOM BANK LIGHTSHIP	VI-1-62 VI-30-62	29
LS POR 79	4114	On station	PORTLANT LIGHT-SHIP	VI-1-62 VI-30-62	15
DEL 62-7	4115	Off Woods Hole to Georges Shoal	DELAWARE	VI-11-62 VI-19-62	66
DEL 62-8	4116	Off Woods Hole to south of Fire Island and return	DELAWARE	VI-25-62 VI-28-62	24
LS NAN 77	4117	On station	NANTUCKET LIGHT-SHIP	VI-1-62 VI-30-62	29
LS AMB 78	4118	On station	AMBROSE LIGHT-SHIP	VI-1-62 VI-30-62	29
LS AMB 79	4119	On station	AMBROSE LIGHT-SHIP	VII-1-62 VII-7-62	7

LS CHE 79	4120	On station	CHESAPEAKE LIGHT-SHIP	VI-1-62 VI-30-62	28
CH 28	4121	Woods Hole to sea and return	CHAIN	VII-6-62 VII-24-62	608
LS FFB 80	4122	On station	FIVE FATHOM BANK LIGHTSHIP	VII-1-62 VII-20-62	20

TABLE I

Bathythermograph Data Received at W.H.O.I. August 1-31, 1962

Cruise No.	Asc. No.	Area	Vessel	Observation Dates	No. of Slides
LS AMB 79	4119	On station	AMROSE LIGHTSHIP	VII-8-62 VII-31-62	24
LS FFB 80	4122	On station	FIVE FATHOM BANK LIGHTSHIP	VII-22-62 VII-31-62	10
BE 280	4123	Off Carolina Coast	BEAR	VII-16-62 VII-29-62	36
AT 282	4124	South of Bermuda to north of Puerto Rico and return	ATLANTIS	VII-11-62 VIII-7-62	33
LS BAR 80	4125	On station	BARNEGAT LIGHTSHIP	VII-1-62 VII-31-62	30
LS CHE 78	4126	On station	CHESAPEAKE LIGHTSHIP	V-1-62 V-31-62	29
LS POR 80	4127	On station	PORTLAND LIGHTSHIP	VII-1-62 VII-31-62	12
CFD 82	4128	Off Woods Hole	CRAWFORD	VIII-4-62 VIII-9-62	9
CFD 83	4129	Out of Woods Hole.	CRAWFORD	VIII-11-62 VIII-15-62	13
LS DEL 18	4130	On station	DELAWARE LIGHTSHIP	VII-1-62 VII-31-62	29
LS BOS 81	4131	On station	BOSTON LIGHTSHIP	VI-1-62 VI-30-62	27
LS SAV 79	4132	On station	SAVANNAH LIGHTSHIP	VII-1-62 VII-31-62	31
LS CHE 71	4133	On station	CHESAPEAKE LIGHTSHIP	X-1-61 X-31-61	28

LS DIA 79	4134	On station	DIAMOND SHOALS LIGHTSHIP	VI-1-62 VI-30-62	29
LS DIA 80	4135	On station	DIAMOND SHOALS LIGHTSHIP	VII-1-62 VII-31-62	31
CFD 84	4136	Woods Hole to Gulf Stream and return	CRAWFORD	VIII-18-62 VIII-26-62	95

TABLE I

Bathythermograph Data Received at W.H.O.I. September 1-30, 1962

Cruise No.	Asc. No.	Area	Vessel	Observation Dates	No. of Slides
LS NAN 72	4137	On station	NANTUCKET LIGHT-SHIP	I-I-62 I-30-62	27
LS BAR 81	4138	On station	BARNEGAT LIGHT-SHIP	VIII-1-62 VIII-31-62	29
LS BOS 83	4139	On station	BOSTON LIGHTSHIP	VIII-2-62 VIII-31-62	23
LS DEL 19	4140	On station	DELAWARE LIGHT-SHIP	VIII-1-62 VIII-31-62	30
LS SAV 80	4141	On station	SAVANNAH LIGHT-SHIP	VIII-1-62 VIII-31-62	29
LS CHE 64	4142	On station	CHESAPEAKE LIGHT-SHIP	III-1-61 III-31-61	28
LS POR 81	4143	On station	PORTLANT LIGHT-SHIP	VIII-2-62 VIII-31-62	30
LS AMB 80	4144	On station	AMBROSE LIGHT-SHIP	VIII-1-62 VIII-31-62	30

TABLE

Bathythermograph Data Received at W.H.O.I. October 1-31, 1962

Cruise No.	Asc. No.	Area	Vessel	Observation Dates	No. of Slides
LS FFB 81	4145	On station	FIVE FATHOM BANK LIGHTSHIP	VIII-1-62 VIII-31-62	29
LS BAR 82	4146	On station	BARNEGAT LIGHT-SHIP	IX-1-62 IX-30-62	30
LS AMB 81	4147	On station	AMBROSE LIGHT-SHIP	IX-1-62 IX-30-62	30
LS CHE 81	4148	On station	CHESAPEAKE LIGHT-SHIP	VIII-1-62 VIII-31-62	29
LS DEL 20	4149	On station	DELAWARE LIGHT-SHIP	IX-1-62 IX-30-62	26
LS FFB 82	4150	On station	FIVE FATHOM BANK LIGHTSHIP	IX-1-62 IX-30-62	27
LS FFB 83	4151	On station	FIVE FATHOM BANK LIGHTSHIP	X-1-62	1
LS POR 82	4152	On station	PORTLAND LIGHT-SHIP	IX-1-62 IX-30-62	26
DEL 62-10	4152	Woods Hole to sea and return	DELAWARE	IX-11-62 IX-20-62	210
LS BOS 84	4154	On station	BOSTON LIGHT-SHIP	IX-1-62 IX-30-62	24
LS FRY 81	4155	On station	FRYING PAN SHOALS LIGHTSHIP	VIII-31-62	1
LS FRY 82	4156	On station	FRYING PAN SHOALS LIGHTSHIP	IX-1-62 IX-30-62	30
LS DIA 81	4157	On station	DIAMOND SHOALS LIGHTSHIP	VIII-1-62 VIII-31-62	30
LS DIA 82	4158	On station	DIAMOND SHOALS LIGHTSHIP	IX-1-62 IX-6-62	6

AT 287	4159	Bermuda to Norfolk	ATLANTIS	X-3-62 X-4-62	23
LS BOS 85	4160	On station	BOSTON LIGHTSHIP	X-1-62 X-19-62	14
CFD 88	4161	Woods Hole to Norfolk and return	CRAWFORD	IX-29-62 X-25-62	179

TABLE I

Bathythermograph Data Received at W.H.O.I. November 1-30, 1962

Cruise No.	Asc. No.	Area	Vessel	Observation Dates	No. of Slides
LS FRY 81	4155	On station	FRYING PAN SHOALS LIGHTSHIP	VIII-1-62 VIII-29-62	20
LS DIA 82	4158	On station	DIAMOND SHOALS LIGHTSHIP	IX-28-62 IX-30-62	3
LS CHE 82	4162	On station	CHESAPEAKE LIGHT-SHIP	IX-1-62 IX-30-62	29
LS BAR 83	4163	On station	BARNEGAT LIGHTSHIP	X-1-62 X-31-62	28
LS DEL 21	4164	On station	DELAWARE LIGHT-SHIP	X-1-62 X-18-62	18
DEL 62-12	4165	Woods Hole to Georges Shoal along 100 fathom curve and return	DELAWARE	X-9-62 XI-3-62	196
LS AMB 82	4166	On station	AMBROSE LIGHTSHIP	X-1-62 X-31-62	31
LS DIA 83	4167	On station	DIAMOND SHOALS LIGHTSHIP	X-1-62 X-31-62	23
LS DIA 84	4168	On station	DIAMOND SHOALS LIGHTSHIP	XI-1-62 XI-4-62	4
LS FRY 83	4169	On station	FRYING PAN SHOALS LIGHTSHIP	X-1-62 X-31-62	25
LS NAN 81	4170	On station	NANTUCKET LIGHT-SHIP	X-18-62 X-31-62	10
LS CHE 80	4171	On station	CHESAPEAKE LIGHT-SHIP	VII-1-62 V11-31-62	none

Cruise No.		Asc. No.	Area	Vessel	Observation Dates	No. of Slides
LS NAN	78	4172	On station	NANTUCKET LIGHT-SHIP	VII-1-62 VII-31-62	27
LS NAN	79	4173	On station	NANTUCKET LIGHT-SHIP	VIII-1-62 VIII-19-62	17
LS NAN	80	4174	On station	NANTUCKET LIGHT-SHIP	IX-1-62 IX-30-62	none
LS BOS	86	4175	On station	BOSTON LIGHTSHIP	XI-1-62	none
CFD	89	4176	Woods Hole to Bermuda and return	CRAWFORD	XI-1-62 XI-20-62	23
E VIII	15	4177	Nassau	EUGENIE VIII	I-19-62 I-29-62	6
CB	3A	4178	Woods Hole to sea	CAP'N BILL III	XI-8-62 XI-14-62	25
AT	288	4179	Off Bermuda	ATLANTIS	XI-9-62 XI-11-62	35
LS BAR	84	4180	On station	BARNEGAT LIGHT-SHIP	XI-1-62 XI-15-62	14

TABLE I

Bathythermograph Data Received at W.H.O.I. December 1-31, 1962

Cruise No.	Asc. No.	Area	Vessel	Observation Dates	No. of Slides
LS BOS 86	4175	On station	BOSTON LIGHT-SHIP	XI-2-62 XI-30-62	28
LS BAR 84	4180	On station	BARNEGAT LIGHT-SHIP	XI-16-62 XI-30-62	11
AT 286	4181	Off Bermuda	ATLANTIS	IX-23-62 XI-25-62	39
LS CHE 83	4182	On station	CHESAPEAKE LIGHTSHIP	X-1-62 X-31-62	28
LS CHE 84	4183	On station	CHESAPEAKE LIGHTSHIP	XI-1-62 XI-30-62	23
LS DEL 21	4164	On station	DELAWARE LIGHT-SHIP	X-22-62 X-31-62	7
LS AMB 71	4184	On station	AMBROSE LIGHT-SHIP	XI-1-61 XI-30-61	26
LS DEL 22	4185	On station	DELAWARE LIGHT-SHIP	XI-1-62 XI-30-62	17
LS DEL 23	4186	On station	DELAWARE LIGHT-SHIP	XII-1-62 XII-6-62	5
LS POR 84	4187	On station	PORTLAND LIGHT-SHIP	XI-1-62 XI-30-62	24
LS SAV 83	4188	On station	SAVANNAH LIGHT-SHIP	XI-1-62 XI-30-62	30
LS SAV 84	4189	On station	SAVANNAH LIGHT-SHIP	XII-1-62	1
DEL 62-15	4190	Off Grand Banks	DELAWARE	XII-5-62 XII-9-62	16
LS FFB 84	4191	On station	FIVE FATHOM BANK LIGHTSHIP	XI-1-62 XI-30-62	25

TABLE I

Bathythermograph Data Received at W.H.O.I. January 1-31, 1963

Cruise No.	Asc. No.	Area	Vessel	Observation Dates	No. of Slides
LS DEL 23	4186	On station	DELAWARE LIGHT-SHIP	XII-8-62 XII-29-62	20
LS AMB 83	4192	On station	AMBROSE LIGHT-SHIP	XI-1-62 XI-30-62	28
LS SAV 81	4193	On station	SAVANNAH LIGHT-SHIP	IX-1-62 IX-29-62	27
LS BAR 85	4194	On station	BARNEGAT LIGHT-SHIP	XII-1-62 XII-31-62	26
LS BOS 87	4195	On station	BOSTON LIGHTSHIP	XII-1-62 XII-29-62	27
GOS 5	4196	Off Woods Hole	GOSNOLD	I-4-63 1-5-63	8
LS POR 83	4198	On station	PORTLANT LIGHT-SHIP	X-1-62 X-31-62	24
LS POR 85	4199	On station	PORTLAND LIGHT-SHIP	XII-1-62 XII-28-62	22
LS FRY 85	4197	On station	FRYING PAN SHOALS LIGHTSHIP	XII-1-62 XII-31-62	14
AT 289	4200	Woods Hole to Nassau to Woods Hole	ATLANTIS	XI-28-62 XII-16-62	87
LS DIA 85	4201	On station	DIAMOND SHOALS LIGHTSHIP	XII-14-62 XII-29-62	12
LS DIA 86	4202	On station	DIAMOND SHOALS LIGHTSHIP	I-2-63	

TABLE I

Bathythermograph Data Received at W.H.O.I. February 1-28, 1963

Cruise No.	Asc. No.	Area	Vessel	Observation Dates	No. of Slides
LS SAV 84	4189	On station	SAVANNAH LIGHT-SHIP	XII-17-62 XII-31-62	11
LS SAV 85	4203	On station	SAVANNAH LIGHT-SHIP	I-2-63 I-31-63	28
LS BOS 88	4204	On station	BOSTON LIGHT-SHIP	I-2-63 I-31-63	29
LS AMB 84	4205	On station	AMBROSE LIGHT-SHIP	XII-1-62 XII-31-62	29
LS DEL 24	4206	On station	DELAWARE LIGHT-SHIP	I-2-63 I-31-63	19
LS FFB 86	4207	On station	FIVE FATHOM BANK LIGHTSHIP	I-4-63 I-31-63	23
LS CHE 85	4208	On station	CHESAPEAKE LIGHT-SHIP	XII-1-62 XII-31-62	23
LS CHE 86	4209	On station	CHESAPEAKE LIGHT-SHIP	I-1-63 I-31-63	30
GOS 6	4210	Woods Hole to Norfolk	GOSNOLD	I-20-63 I-23-63	6
CB 2	4211	Off Woods Hole	CAP'N BILL III	X-23-62 X-31-62	no slides received
CB 4-A	4212	Off Woods Hole	CAP'N BILL III	XI-29-62 XII-2-62	14
CB 5-A	4213	Off Woods Hole	CAP'N BILL III	I-30-63 II-4-63	23
LS AMB 85	4214	On station	AMBROSE LIGHT-SHIP (RELIEF)	I-1-63 I-17-63	15
LS POR 86	4215	On station	PORTLAND LIGHT-SHIP	I-13-63 I-31-63	19
LS BAR 86	4216	On station	BARNEGAT LIGHT-SHIP	I-1-63 I-31-63	29

TABLE I

Bathythermograph Data Received at W.H.O.I. March 1-31, 1963

Cruise No.	Asc. No.	Area	Vessel	Observation Dates	No. of Slides
CB 2a	4211	Off Woods Hole	CAPT BILL III	X.23.62 X.21.62	18
CB 6a	4217	Off Woods Hole to Cape Hatteras	CAPT BILL III	11.25.63 111.1.63	11
LS.FRY. 86	4218	On Station	FRYING PAN SHOALS LIGHTSHIP	1.1.63 1.21.63	19
LS.SAV. 86	4219	On Station	SAVANNAH LIGHTSHIP	11.1.63 11.28.63	26
LS.NAN.85	4220	On Station	NANTUCKET LIGHTSHIP	11.1.63 11.28.63	16
LS.BAR.87	4221	On Station	BARNEGAT LIGHTSHIP	11.1.63 11.28.63	26
LS.DEL.25	4222	On Station	DELAWARE LIGHTSHIP	11.1.63 11.28.63	23
LS.FFB.87	4223	On Station	FIVE FATHOM BANK LIGHTSHIP	11.1.63 11.28.63	22
LS.FFB.88	4224	On Station	FIVE FATHOM BANK LIGHTSHIP	111.1.63	1
LS.POR.87	4225	On Station	PORTLAND LIGHTSHIP	11.1.63 11.28.63	27
LS.AMB.86	4226	On Station	AMBROSE LIGHTSHIP	11.2.63 11.28.63	24
LS.BOS.89	4227	On Station	BOSTON LIGHTSHIP	11.1.63 11.28.63	24

TABLE I

Bathythermograph Data Received at W.H.O.I. April 1 - 30, 1963

Cruise No.	Asc. No.	Area	Vessel	Observation Dates	No. of Slides
LS.FFB.88	4224	On Station	FIVE FATHOM BANK LIGHTSHIP	111.2.63 111.31.63	30
LS.BAR.88	4228	On Station	BARNEGAT LIGHTSHIP	111.1.63 111.31.63	3
LS.DEL.26	4229	On Station	DELAWARE LIGHTSHIP	111.1.63 111.31.63	30
LS.NAN.82	4230	On Station	NANTUCKET SHOALS LIGHTSHIP	X1.1.62 X1.29.62	10
LS.NAN.83	4231	On Station	NANTUCKET LIGHTSHIP	X11.1.62 X11.29.62	10
LS.NAN.86	4232	On Station	NANTUCKET LIGHTSHIP	111.1.63 111.31.63	17
LS.AMB.87	4233	On Station	AMBROSE LIGHTSHIP	111.1.63 111.31.63	31
AT II - 1	4234	Southwest of Bermuda	ATLANTIS II	111.1.63 111.19.63	4
LS.POR.88	4235	On Station	PORTLAND LIGHTSHIP	111.1.63 111.31.63	28
AT II - 2	4236	Woods Hole to Halifax and return (Search for THRESHER)	ATLANTIS II	1V.5.63 1V.16.63	56
TH. 1	4237	Searching for THRESHER	USS WARRINGTON	1V.14.63 1V.15.63	39
LS.CHE.87	4238	On Station	CHESAPEAKE LIGHTSHIP	11.1.63 11.28.63	26
LS.FRY.87	4239	On Station	FRYING PAN SHOALS LIGHTSHIP	11.1.63 11.28.63	15
LS.FRY.88	4240	On Station	FRYING PAN SHOALS LIGHTSHIP	111.1.63 111.18.63	13
LS.BOS.90	4241	On Station	BOSTON LIGHTSHIP	111.1.63 111.31.63	30

CB 2a	4211	Off Woods Hole	CAPT BILL III	X.23.62 X.31.62*	18

* Correction from last months report.

TABLE I

Bathythermograph Data Received at W.H.O.I. May 1 - 31, 1963

Cruise No.	Asc. No.	Area	Vessel	Observation Dates	No. of Slides
LS.DIA. 86	4202	On station	DIAMOND SHOALS LIGHTSHIP	1.17.63 1.29.63	13
CFD 91	4242	Bermuda to Cape Verde to Recife to equator to Recife to equator to Recife to St. Thomas to Woods Hole.	CRAWFORD	1.24.63 1V. 28.63	1226
LS. BOS. 91	4243	On station	BOSTON LIGHT-SHIP	1V.3.63 1V.30.63	27
LS. DEL 27	4244	On station	BELAWARE LIGHTSHIP	1V.1.63 1V.30.63	29
LS. BAR 89	4245	On station	BARNEGAT LIGHT-SHIP	1V.1.63 1V.30.63	24
LS. AMB.88	4246	On station	AMBROSE LIGHT-SHIP	1V.1.63 1V.29.63	29
LS. DIA. 87	4247	On station	DIAMOND SHOALS LIGHTSHIP	11.2.63 11.28.63	12
LS. DIA. 88	4248	On station	DIAMOND SHOALS LIGHTSHIP	111.1.63 111.31.63	11
LS.DIA. 89	4249	On station	DIAMOND SHOALS LIGHTSHIP	1V.1.63 1V.29.63	25
LS. DIA. 90	4250	On station	DIAMOND SHOALS LIGHTSHIP	V.1.63 V.4.63	4
A. 63. 1	4251	Woods Hole to Georges Shoal and return	ALBATROSS IV	V.13.63 V.17.63	27
LS. FFB. 89	4252	On station	FIVE FATHOM BANK LIGHTSHIP	1V.1.63 1V.30.63	29
LS. SAV. 88	4253	On station	SAVANNAH LIGHT-SHIP	1V.10.63 1V.30.63	20

TABLE I

Bathythermograph Data Received at W.H.O.I. June 1 - 30, 1963

Cruise No.	Asc. No.	Area	Vessel	Observation Dates	No. of Slides
Del 62-16	4254	Off Georges Shoal to Cape Cod	DELAWARE	X11.14.62 X11.19.62	32
GOS.15	4255	Off Woods Hole	GOSNOLD	V.25.63 V.30.63	31
GOS.14	4256	Off Woods Hole	GOSNOLD	V.22.63 V.23.63	4
LS.NAN.87	4257	On station	NANTUCKET LIGHTSHIP	1V.1.63 1V.30.63	19
Del 62-15	4258	Off Nantucket Shoals to Cape Cod	DELAWARE	X1.17.62 X1.20.62	13
LS.AMB.89	4259	On station	AMBROSE LIGHT-SHIP	V.1.63 V.31.63	30
LS.BOS.92	4260	On station	BOSTON LIGHT-SHIP	V.1.63 V.31.63	30
LS.DEL.28	4261	On station	DELAWARE LIGHT-SHIP	V.1.63 V.31.63	28
LS.FFB.90	4262	On station	FIVE FATHOM BANK LIGHTSHIP	V.1.63 V.31.63	27
LS.CHE.89	4263	On station	CHESAPEAKE LIGHT-SHIP	IV.1.63 1V.30.63	22
A.63-3	4264	Woods Hole to 100 fm curve and return	ALBATROSS IV	V1.10.63 V1.13.63	98
A.63-5	4265	Off Woods Hole	ALBATROSS IV	V1.19.63 V1.24.63	20
LS.FRY.89	4266	On station	FRYING PAN SHOALS LIGHTSHIP	1V.1.63 1V.30.63	20
LS.FRY.90	4267	On station	FRYING PAN SHOALS LIGHTSHIP	V.1.63 V.31.63	17
C FD 93	4268	Woods Hole to Bermuda and return	CRAWFORD	V1.5.63 V1.21.63	263

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